Claims

1. A peak to average power ratio reducer for a multi-carrier modulation (MCM) communication system comprising:

a normalizer for receiving a MCM signal having a plurality of data samples, wherein the plurality of data samples represent at least a plurality of amplitude values, the normalizer for determining a maximum amplitude value from the plurality of amplitude values, and for dividing each of the plurality of amplitude values by the maximum amplitude value to produce a plurality of normalized amplitude values, and the normalizer having an output for providing a normalized MCM signal comprising a plurality of normalized data samples representing the plurality of normalized amplitude values; and

a hybrid amplifier having an input coupled to the output of the normalizer, the hybrid amplifier for receiving the plurality of normalized data samples, for comparing each of the plurality of normalized amplitude values with at least one predetermined amplitude value criteria, the hybrid amplifier for linearly amplifying the normalized amplitude values of at least some of the plurality of normalized data samples when the amplitude values of the at least some of the plurality of normalized data samples satisfy the predetermined amplitude value criteria, and the hybrid amplifier for non-linearly amplifying normalized amplitude values of some other of the plurality of normalized data samples when the normalized amplitude values of the at least some other of the plurality of normalized data samples do not satisfy the predetermined amplitude criteria, and for producing a plurality of amplified amplitude values, the hybrid amplifier having an output for providing a MCM signal comprising the plurality of amplified amplitude values.

2. A peak to average power ratio reducer in accordance with claim 1 wherein the normalizer comprises a mathematical processor for

implementing equation $A = (N-2)\sqrt{\frac{2P_s}{N}}$ to determine the maximum amplitude value, where A is the maximum amplitude value, N is the number of sub-carriers in the multi-carrier modulation communication system, and P_S is the signal power of each of the sub-carriers.

3. A peak to average power ratio reducer in accordance with claim 2 wherein the normalizer comprises a memory coupled to the input for storing the plurality of data samples.

4. A peak to average power ratio reducer in accordance with claim 1 wherein the hybrid amplifier comprises a digital linear amplifier having an input for receiving the normalized amplitude values of the at least some of the plurality of normalized data samples, the digital linear amplifier for amplifying the received normalized amplitude values by a predetermined amplification factor to produce some of the plurality of amplified amplitude values.

5. A peak to average power ratio reducer in accordance with claim 4 wherein the amplification factor comprises a factor greater than unity.

6. A peak to average power ratio reducer in accordance with claim 4 wherein the hybrid amplifier comprises a digital non-linear amplifier having an input for receiving the normalized amplitude values of the at least some other of the plurality of normalized data samples, the digital non-linear amplifier for amplifying the received normalized amplitude values of the at least some other of the plurality of normalized data samples by a predetermined non-linear function to produce some other of the plurality of amplified amplitude values.

7. A peak to average power ratio reducer in accordance with claim 6 wherein the amplification function comprises a logarithmic function.

8. A peak to average power ratio reducer in accordance with claim 6 wherein the amplification function comprises a trajectory function.

9. A peak to average power ratio reducer in accordance with claim 6 wherein the hybrid amplifier comprises at least a first digital comparator being coupled to receive the normalized amplitude values of the plurality of normalized data samples, and being coupled to receive the predetermined amplitude value criteria, wherein the predetermined amplitude value criteria comprises a range of amplitude values having minimum and maximum amplitude values, and the at least the first digital comparator being coupled to the digital linear amplifier, the at least the first digital comparator for comparing each of the normalized amplitude values of the plurality of normalized data samples with the range of amplitude values, and the at least the first digital comparator being adapted to enable the digital linear amplifier when the normalized amplitude values of the at least some of the plurality of normalized data samples are received, wherein the amplitude values of the at least some of the plurality of normalized data samples are within the range of amplitude values.

10. A peak to average power ratio reducer in accordance with claim 9 wherein the hybrid amplifier comprises at least a second digital comparator being coupled to receive the normalized amplitude values of the plurality of normalized data samples, and being coupled to receive the maximum amplitude value, wherein the digital non-linear amplifier comprises a first digital non-linear amplifier module, and the at least the second digital comparator being coupled to the first digital non-linear amplifier module, the at least the second digital comparator for comparing each of the normalized amplitude values of the plurality of normalized data samples with the maximum amplitude value, and the at least the second digital comparator being adapted to enable the first

digital non-linear amplifier module when the normalized amplitude values of the at least some other of the plurality of normalized data samples are received, wherein the amplitude values of the some other of the plurality of normalized data samples are greater than the maximum amplitude value.

11. A peak to average power ratio reducer in accordance with claim 10 wherein the at least the second digital comparator being coupled to the second digital non-linear amplifier module, and being coupled to receive the minimum amplitude value, the at least the second digital comparator for comparing each of the normalized amplitude values of the plurality of normalized data samples with the minimum amplitude value, and the at least the second digital comparator being adapted to enable the second digital non-linear amplifier module when the normalized amplitude values of the at least some of other of the plurality of normalized data samples are received, wherein the amplitude values of the some other of the plurality of normalized data samples are less than the minimum amplitude value.

12. A peak to average power ratio reducer in accordance with claim 11 wherein the first and second digital non-linear amplifier modules are logarithmic amplifiers.

13. A peak to average power ratio reducer in accordance with claim 11 wherein the first and second digital non-linear amplifier modules are trajectory amplifiers.

14. A peak to average power ratio reducer in accordance with claim 11 wherein the first digital non-linear amplifier module is a logarithmic amplifier, and wherein the second digital non-linear amplifier module is a trajectory amplifier.

15. A peak to average power ratio reducer in accordance with claim 11 wherein the first digital non-linear amplifier module is a trajectory amplifier, and wherein the second digital non-linear amplifier module is a logarithmic amplifier.

16. A peak to average power ratio reducer in accordance with claim 1 comprising at least one programmed digital signal processor.

17. A peak to average power ratio reducer in accordance with claim 1, wherein the normalizer comprises at least one programmed digital signal processor.

18. A peak to average power ratio reducer in accordance with claim 1, wherein the hybrid amplifier comprises at least one programmed digital signal processor.

19. A receiver for a multi-carrier modulation (MCM) communication receiver comprising:

a hybrid amplifier having an input for receiving a PAPR reduced MCM signal, the PAPR reduced MCM signal comprising a plurality of PAPR reduced data samples, wherein each of the plurality of PAPR reduced data samples comprise an amplitude value, and the hybrid amplifier having an output for providing a PAPR restored MCM signal comprising a plurality of PAPR restored data samples, wherein each of the plurality of PAPR restored data samples comprises a restored amplitude value.

20. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 19, wherein the hybrid attenuator comprises a digital linear attenuator for receiving the amplitude values of the plurality of PAPR reduced data samples, the digital linear attenuator for attenuating the received amplitude values by a

predetermined attenuation factor to produce some of the plurality of restored data samples having some of the restored amplitude values.

21. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 20, wherein the attenuation factor comprises a factor less than unity.

22. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 19, wherein the hybrid attenuator comprises a digital non-linear attenuator for receiving the amplitude values of the plurality of PAPR reduced data samples, the digital non-linear attenuator for attenuating the received amplitude values by a predetermined non-linear function to produce some other of the plurality of restored data samples having some other of the restored amplitude values.

23. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 22, wherein the predetermined non-linear function comprises an inverse logarithmic function.

24. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 22, wherein the predetermined non-linear function comprises an inverse trajectory function.

25. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 20, wherein the hybrid attenuator comprises at least a first digital comparator being coupled to receive the amplitude values of the plurality of PAPR reduced data samples, and being coupled to receive a predetermined amplitude value criteria, wherein the predetermined amplitude value criteria comprises a range of amplitude values having minimum and maximum amplitude values, and the at least the first digital comparator being coupled to the digital

linear attenuator, the at least the first digital comparator for comparing each of the amplitude values of the plurality of PAPR reduced data samples with the range of amplitude values, and the at least the first digital comparator being adapted to enable the digital linear attenuator when the amplitude values of the some of the plurality of restored data samples are received, wherein the amplitude values of the some of the plurality of PAPR reduced data samples are within the range of amplitude values.

26. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 25, wherein the hybrid attenuator comprises at least a second digital comparator being coupled to receive the amplitude values of the plurality of PAPR reduced data samples, and being coupled to receive the maximum amplitude value, wherein the non-linear attenuator comprises a first digital non-linear attenuator module, and the at least the second digital comparator being coupled to the first digital non-linear attenuator module, the at least the second digital comparator for comparing each of the amplitude values of the plurality of PAPR reduced data samples with the maximum amplitude value, and the at least the second digital comparator being adapted to enable the first digital non-linear attenuator module when the amplitude values of the some other of the plurality of PAPR reduced data samples are received, wherein the amplitude values of the some other of the plurality of PAPR reduced data samples are greater than the maximum amplitude value.

27. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 26, wherein the at least the second digital comparator being coupled to the second digital non-linear attenuator module, and being coupled to receive the minimum amplitude value, the at least the second digital comparator for comparing each of the amplitude values of the plurality of PAPR

reduced data samples with the minimum amplitude value, and the at least the second digital comparator being adapted to enable the second digital non-linear attenuator module when the amplitude values of the some other of the plurality of PAPR reduced data samples are received, wherein the amplitude values of the some other of the plurality of PAPR reduced data samples are less than the minimum amplitude value.

28. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 27, wherein the first and second digital non-linear attenuator modules are inverse logarithmic attenuators.

29. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 27, wherein the first and second digital non-linear attenuator modules are inverse trajectory amplifiers.

30. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 27, wherein the first digital non-linear attenuator module is an inverse logarithmic attenuator, and wherein the second digital non-linear attenuator module is an inverse trajectory attenuator.

31. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 19 comprising at least one programmed digital signal processor.

32. A receiver for a multi-carrier modulation (MCM) communication receiver in accordance with claim 19 wherein the hybrid amplifier comprises at least one programmed digital signal processor.

33. A method for peak to average power ratio reduction for a multi-carrier modulation transmission system, the method comprising the steps of:

a) receiving a MCM signal comprising a plurality of data sample, wherein each of the plurality of data samples represent an amplitude value;

b) normalizing each of the plurality of amplitude values with respect to a maximum amplitude value of the plurality of amplitude values to produce a plurality of normalized data samples having normalized amplitude values;

c) comparing each of the normalized amplitude values with a predetermined range of amplitude values, wherein the predetermined range comprises a maximum amplitude value and a minimum amplitude value;

d) amplifying the normalized amplitude values linearly when the normalized amplitude values are within the predetermined range of amplitude values;

e) comparing the normalized amplitude values with the maximum amplitude value;

f) amplifying the normalized amplitude values non-linearly in accordance with a first non-linear function when the normalized amplitude values are greater than the maximum amplitude value;

g) comparing the normalized amplitude values with the minimum amplitude value;

h) amplifying the normalized amplitude values non-linearly in accordance with a second non-linear function when the normalized amplitude values are less than the minimum amplitude value; and

i) providing a PAPR reduced MCM signal comprising a plurality of amplified data samples representing the linearly amplified amplitude values, and the non-linearly amplified amplitude values in accordance with the first and second non-linear functions.

34. A method in accordance with claim 33 wherein step (b) comprises the steps of:

determining the maximum amplitude value of the plurality of data samples; and

dividing the amplitude values of substantially all of the plurality of samples by the maximum amplitude value to produce the plurality of normalized data samples having normalized amplitude values.

35. A method for restoring a peak to average power ratio reduced signal for a multi-carrier modulation receiving system, the method comprising the steps of:

a) receiving a PAPR reduced MCM signal comprising a plurality of PAPR reduced data samples, wherein each of the plurality of PAPR reduced data samples represent an amplified amplitude value;

b) comparing the amplified amplitude values with a predetermined range of amplitude values, wherein the predetermined range comprises a maximum amplitude value and a minimum amplitude value;

c) attenuating the amplified amplitude values linearly when the received amplified amplitude values are within the predetermined range of amplitude values;

d) comparing the amplified amplitude values with the maximum amplitude value;

e) attenuating the amplitude value of the received amplified amplitude values non-linearly in accordance with a first non-linear function when the received amplified amplitude values are greater than the maximum amplitude value;

f) comparing the amplified amplitude values with the minimum amplitude value;

g) attenuating the amplified amplitude values non-linearly in accordance with a second non-linear function when the amplified amplitude values are less than the minimum amplitude value; and

h) providing a restored MCM signal comprising a plurality of PAPR restored data samples representing the linearly attenuated amplitude values, and the non-linearly attenuated amplitude values in accordance with the first and the second non-linear functions.